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MOTION CHARACTERISTICS OF NRL PLATFORM (FORDS) IN WAVES

by

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COLLECTION

John Foster

Hydromechanics Laboratory

RESEARCH AND DEVELOPMENT REPORT

August 1964

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ABSTRACT

The David Taylor Model Basin was requested to make a quantitative study of the motion characteristics of the NRL Alternate 1 Stable Platform Concept (FORDS). Tests were conducted in the Seakeeping Facility on a 1/40-scale model in regular and irregular waves. In general, the motions at the light draft were comparable in magnitude to those of a cargo-type ship of the same displacement. However, at the deep or operating draft, the motion of the platform was reduced considerably.

INTRODUCTION

The Naval Research Laboratory is conducting feasibility studies of stable platforms to determine requirements for testing and evaluating large, low-frequency, acoustic transducers in ocean surveillance applications. An important part of this work is to make accurate measurements of the motions of scaled models in order to reach decisive conclusions on a suitable stable platform configuration. As a part of this study, the Taylor Model Basin was requested to conduct scaled model tests of a proposed stable platform design.[1]

In January 1963, a 1/120-scale model of NRL Alternate 1 Stable Platform Concept (FORDS) was tested in the TMB 140-ft basin. Because of the small model and the instrumentation limitations, only qualitative results were obtained. It was then decided to test a larger model (1/40-scale) in the Maneuvering and Seakeeping Facility, and these tests were conducted in November 1963.

---

[1] References are listed on page 7

DESCRIPTION OF MODEL AND PROTOTYPE

The 1/40-scale model of the NRL Platform was constructed of wood and metal in such a manner as to ensure meeting the weight and mass distribution requirements of the full-scale structure. Table 1 presents principal dimensions and dynamic properties of the prototype. The test conditions for the five displacements, which include the drafts, weights, and natural periods at these conditions, are listed in this table. Photographs of the model are shown in Figure 1.

TEST PROCEDURES AND EQUIPMENT

Tests were run in regular and irregular waves with the model completely free in all six degrees of freedom. During the tests, the model was allowed to drift in the direction of the wave train. A light nylon line was used to orient the platform in yaw when the model exhibited a tendency to become aligned perpendicular to the wave direction.

Tests were conducted in regular waves (in head and beam seas) corresponding to full-scale wave lengths, λ = 200 to 2400 ft; and wave height to wave length ratios h/λ = 1/25 to 1/60. They were conducted for most of the displacement conditions; see Table 1.

Results obtained from tests in regular waves made it necessary to conduct tests in irregular waves corresponding to States 4 and 6 seas so that the motion response of the platform could be determined for a more natural environment. All five displacement conditions were tested for different headings relative to the seas; that is, 0, 45, and 90 deg.

An aircraft-type gyroscope was installed in the model to measure pitch and roll angles, and Donner accelerometers were used to measure heave, sway, and surge motions. Data were recorded on both paper charts and magnetic tape. Motion pictures were taken during the tests. This film was used in the analysis of the heave data for some of the regular wave tests.

TABLE 1

Characteristics of NRL Platform (FORDS)

Principal Dimensions[A]

Length	242 ft
Breadth	225 ft
Height (legs retracted)	340 ft

Dynamic Properties[B] of Displacement Condition 1

Vertical Distance of Center of Gravity above Base of Platform	52.8 ft
Vertical Distance of Metacenter above Base of Platform (about Roll Axis)	284.6 ft
Pitch Gyradius	94.2 ft
Roll Gyradius	96.2 ft

Test Conditions

Displacement	Draft ft	Weight Long Tons	Natural Periods, Sec Pitch	Heave	Roll
1	30	13,510	13.4	5.3	8.7
2	30	13,950	13.8	5.6	10.6
3	42	17,260	51.5	22.7	25.5
4	265	19,220	50.8	123.3	55.1
5	125	13,920	59.4	126.5	62.5

[A] See Reference 2 for detailed dimensions.

[B] These properties were changed for each displacement condition by filling selected ballast tanks with water and chemical salts. These particular tanks were sufficiently filled such that free surface effects can be ignored.

RESULTS OF TESTS IN REGULAR WAVES

Results of the tests in regular waves indicated that the model response to a given wave length was nonlinear with respect to wave height. Test results for the displacement conditions showed that the general trend was for the linearity to improve with increase in displacement.

Regular wave data were obtained for Conditions 1 and 4 in the linear range. Figure 2 shows the results of the tests for the two conditions, and Figures 3 and 4 show the frequency response curves for these conditions. Most of these results cannot be utilized as valid estimators of the platform motions in seas greater than States 3 and 4. They do, however, provide some insight into the behavior of the platform in waves.

It is readily apparent that the motions are reduced considerably with the platform in the deep draft condition. The heave amplitude is large for wave periods of 10 to 14 sec in displacement Condition 1 (light draft). Fortunately, the natural period in heave is 5.3 sec. These curves may be considered indicative of the maximum vertical motions to be expected. This unusual peaking of these curves near the natural periods of pitch and roll suggest strong coupling between these motions and heave. The heave amplitude curve is quite smooth for displacement Condition 4. However, the curve is not complete in the low-frequency range because of physical limitations of the wavemaker system. It is not expected that a peaking or resonance condition will occur in this low-frequency range because of the natural heave frequency of the platform is very low compared to the frequencies of waves normally encountered in a seaway.

The pitch and roll motions show similar characteristics with respect to frequency content. The peaking of these curves for displacement Condition 1 occurs in the vicinity of the natural periods of pitch and roll. The natural frequencies for pitch and roll for displacement Condition 4 are much lower than will be found in a given seaway and should have no effect on peaking the response curve. This is shown in Figure 4.

RESULTS OF TESTS IN IRREGULAR WAVES

As mentioned previously, tests in irregular waves were conducted for simulated State 4 and 6 seas. The irregular wave data provided a more realistic estimation of the performance of the prototype in waves. These test results represent, in a probabilistic sense, the motion of the platform in the particular sea environment simulated during the tests.

Time histories of wave height, pitch angle, roll angle, and heave, surge, and sway accelerations were recorded and spectrum analyzed. It was physically impossible to locate the heave accelerometer at the center of the roll axis. As a result, the determination of heave acceleration, in the beam sea conditions, is actually a measure of the platform's vertical motion approximately 2 feet from the center of the model roll axis. Therefore, the heave motion in the beam sea conditions do not accurately reflect the vertical motion of the platform's center of gravity particularly in displacement conditions 1 and 2 where the roll motions are large. The heave accelerometer was located at the pitch axis so there is no similar effect in the head sea condition.

The random wave results are presented in Figures 5 through 28. From these figures, the relative amounts of energy at different frequencies and the frequency at which maximum energy occurs are apparent by observation. By integrating the areas under the curves, statistical estimates of the various motions can be computed. For example, the area under the spectrum curve is equal to twice the mean square value of the signal:

$$\text{Area} = E = 2\sigma^2$$

$$\text{or the rms} = \sqrt{E/2} = \sigma.$$

The average peak-to-peak values are related to the E value as follows:

Average value (peak-to-peak)

$$\bar{h} = 1.77\sqrt{E}$$

Average of 1/3 highest value

$$\bar{h}\ 1/3 = 2.83\sqrt{E}$$

Average of 1/10 highest value

$$\bar{h}\ 1/10 = 3.60\sqrt{E}$$

TABLE 2

Summary of Irregular Wave Data for NRL Platform (FORDS)

Run No.	Displacement Condition	Sea State	Heading	Average Values (Peak-to-Peak) Pitch deg	Roll deg	Heave ft
18	1	4[A]	Head	1.72	---	2.50
21			Beam	----	3.34.	4.09
24		6[B]	Head	4.47	0.50	4.56
27			Beam	----	6.30	6.08
73	2		Head	3.31	0.60	5.02
75			Beam	----	5.57	5.05
77			Oblique[C]	2.19	4.30	3.66
79		4	Head	2.19	----	2.79
81			Beam	----	3.78	3.32
83			Oblique	1.34	2.40	1.98
112	3	6	Head	1.27	---	4.05
114			Oblique	0.89	1.32	2.44
116			Beam	----	1.47	3.52
144	4	6	Head	0.90	----	0.51
146			Oblique	0.68	0.52	0.35
148			Beam	----	1.12	0.50
180	5	6	Head	0.54	---	1.27
181			Beam	----	0.55	1.68

[A] Average wave height is 4.4 ft; period of maximum energy is approximately 9.1 sec.

[B] Average wave height is 8.5 ft; period of maximum energy is approximately 9.4 sec.

[C] Head of model is 45 deg to seaway.

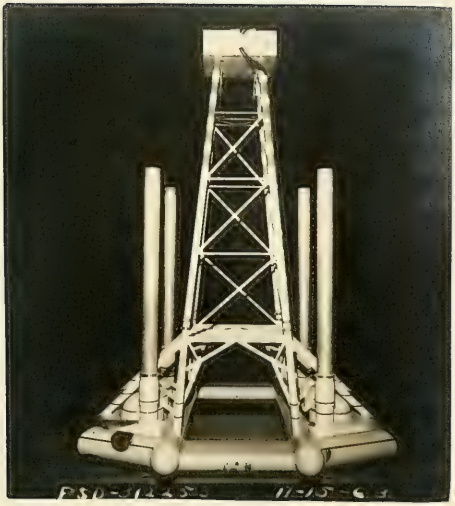
The results of the irregular wave tests are summarized in Table 2, which presents the average peak-to-peak values of pitch, roll, and heave for the various draft conditions tested. It is apparent from the data in this table that the motions are reduced considerably in the heavy draft condition. For example, in a State 6 sea, the heave motion for Condition 4 is about 1/10 to 1/20 of the corresponding motions in Condition 1 and the pitch motion is about 1/5.

SUMMARY

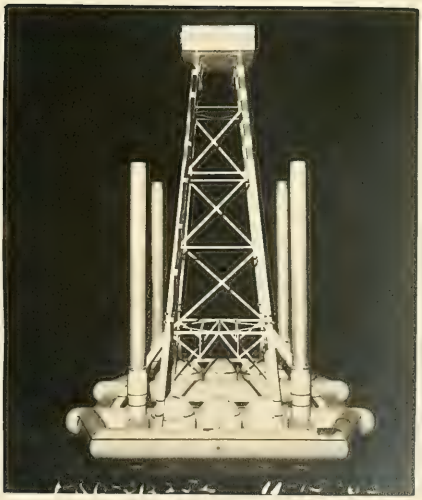
The test results show that as the draft or displacement of the model increases, the motions in general decrease for a given sea state. Certainly, the motions of the platform increase with increase in sea state for a given draft or displacement. The model tends to roll more in a beam sea than it pitches in a head sea. The motions in the oblique heading (bow seas or 45 deg from the head) were generally less than in the head or beam heading for the same condition.

REFERENCES

1. NRL letter 5520-58 REF/cc NRL Problem 501-21, Serial 2215 of 10 Mar 1961.
2. Department of the Navy, Bureau of Yards and Docks, Drawings of Project NBY-2378.



Front View of Model with Legs in Retracted Position



Side View of Model with Legs in Retracted Position

Figure 1 - 1/40-Scale Model of NRL Alternate 1 Stable Platform Concept (FORDS)

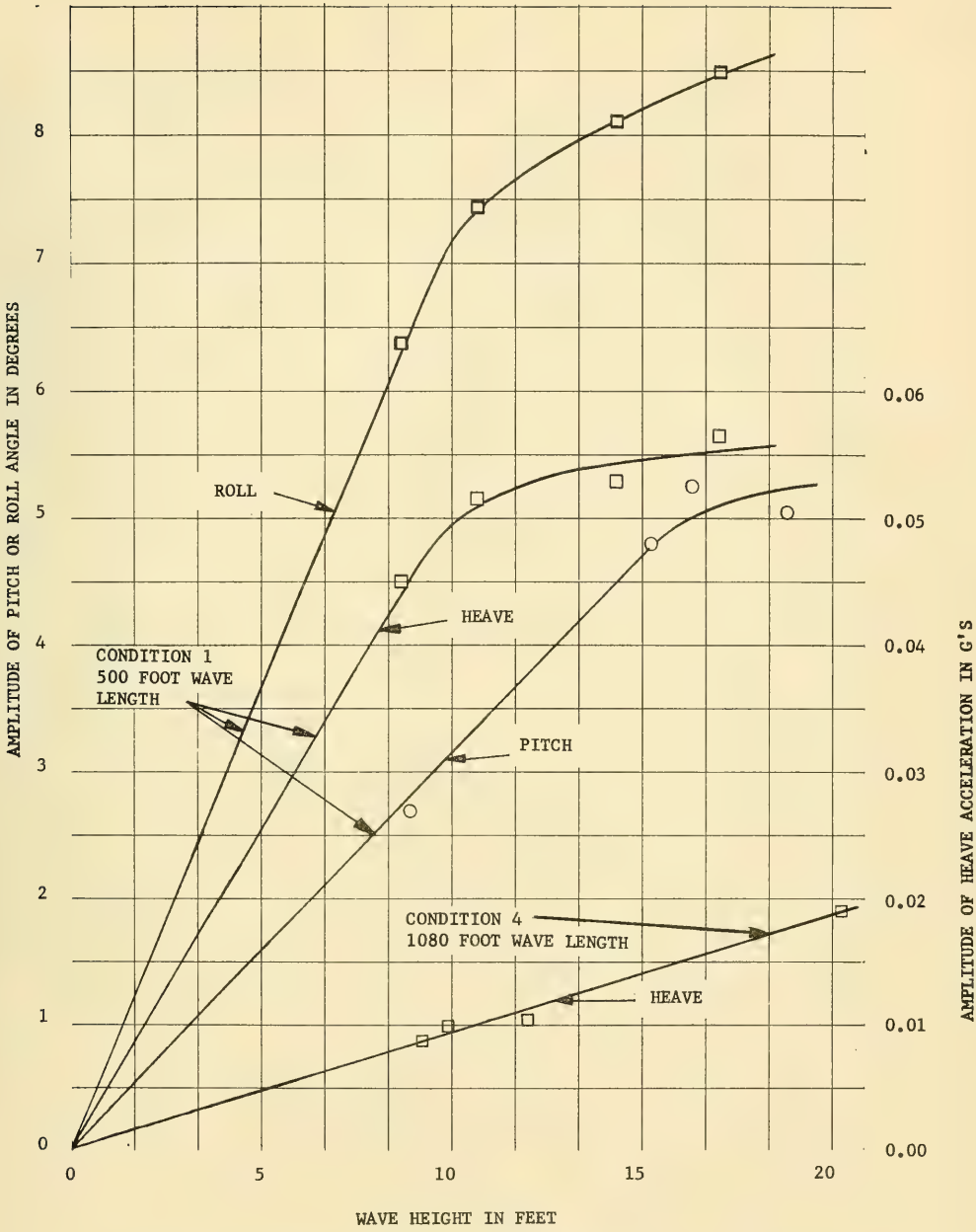


Figure 2 - Linearity Investigation for Various Motions in Regular Waves for the NRL Platform (FORDS)

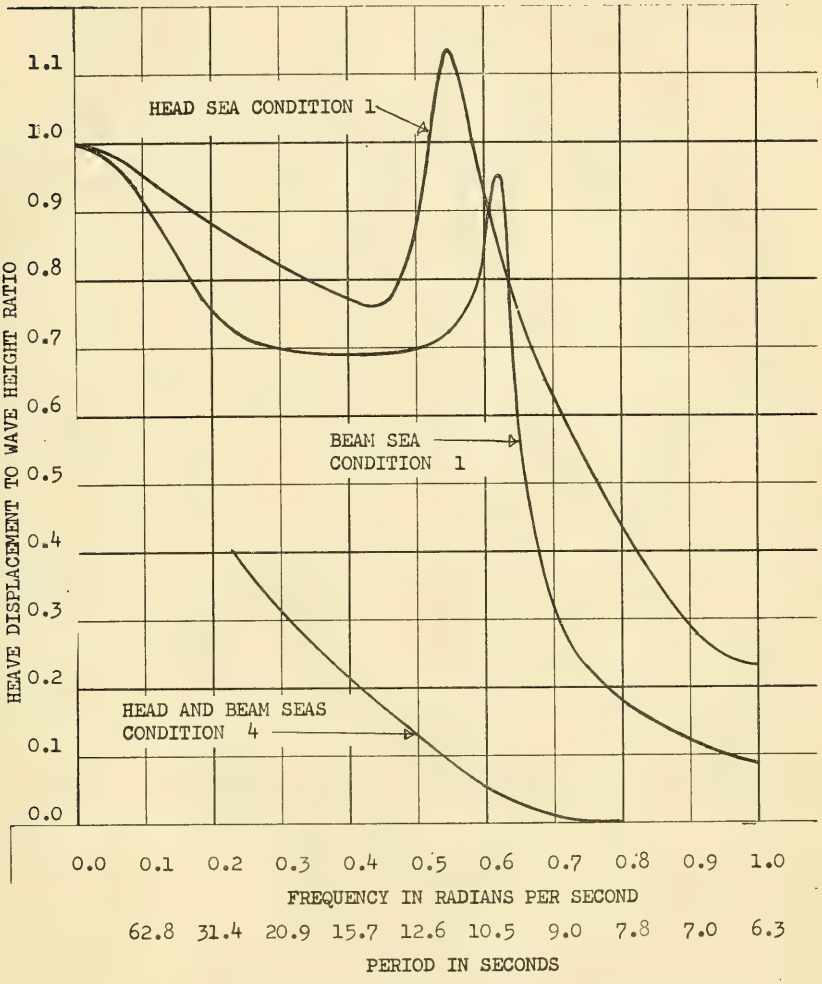


Figure 3 - Heave Response in Regular Waves of Small Amplitude for the NRL Platform (FORDS)

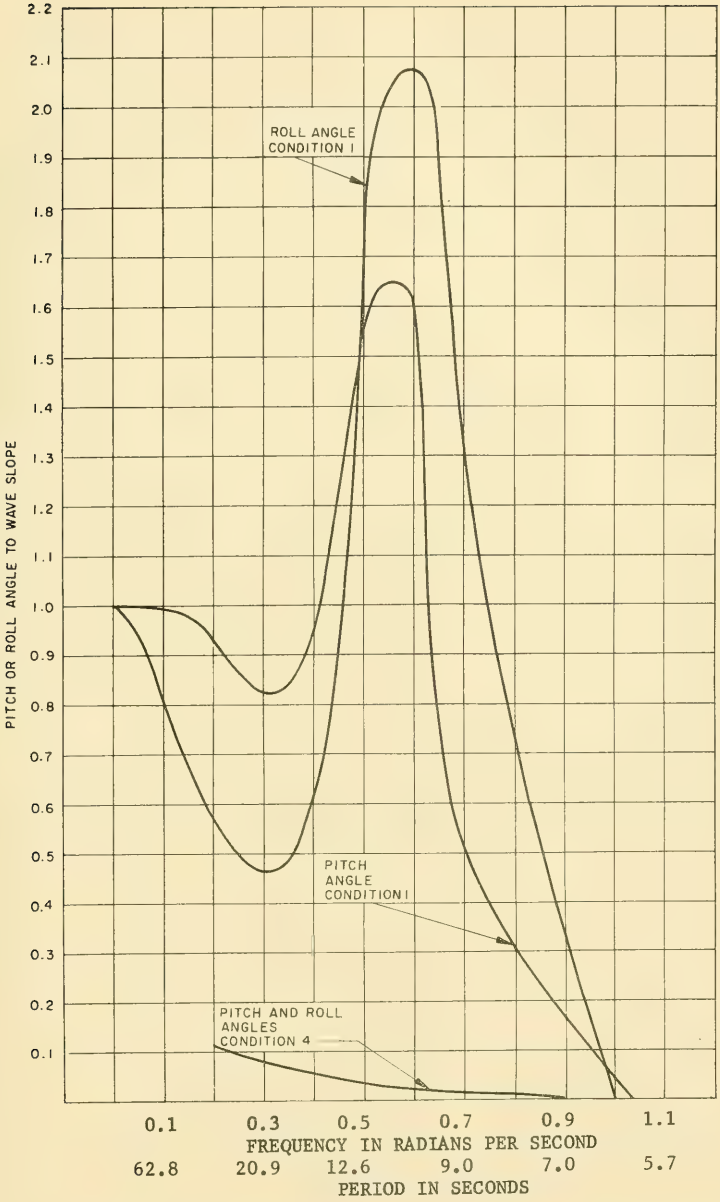


Figure 4 - Pitch and Roll Responses in Regular Waves of Small Amplitude for the NRL Platform (FORDS)

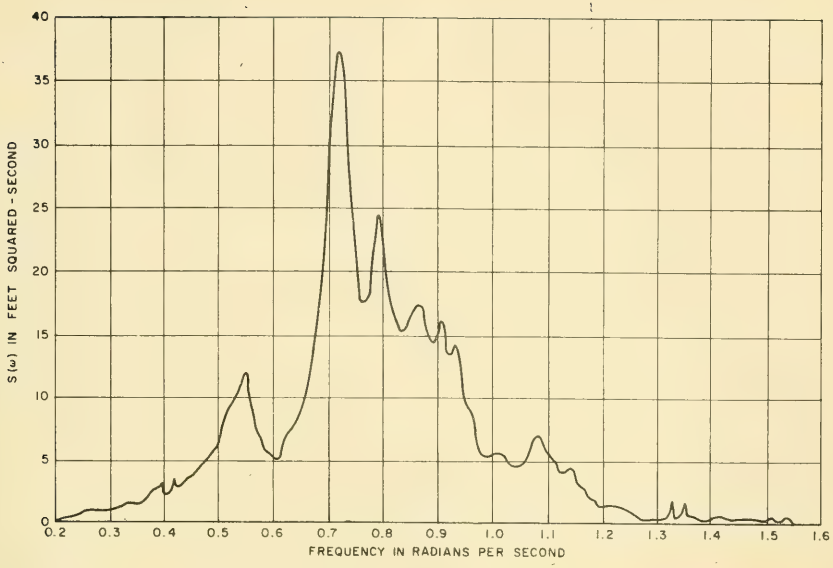


Figure 5 - Power Density Spectrum of Wave Height Used during Test to Simulate State 4 Sea

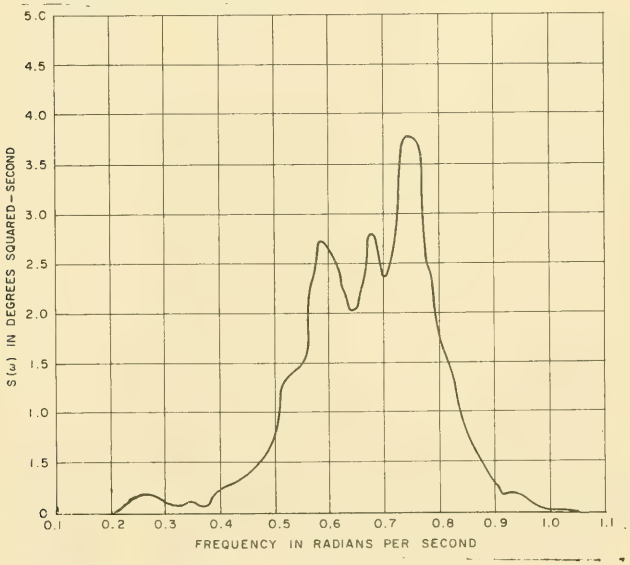


Figure 6 - Power Density Spectrum of Pitch Angle for Condition 1 in a Head State 4 Sea

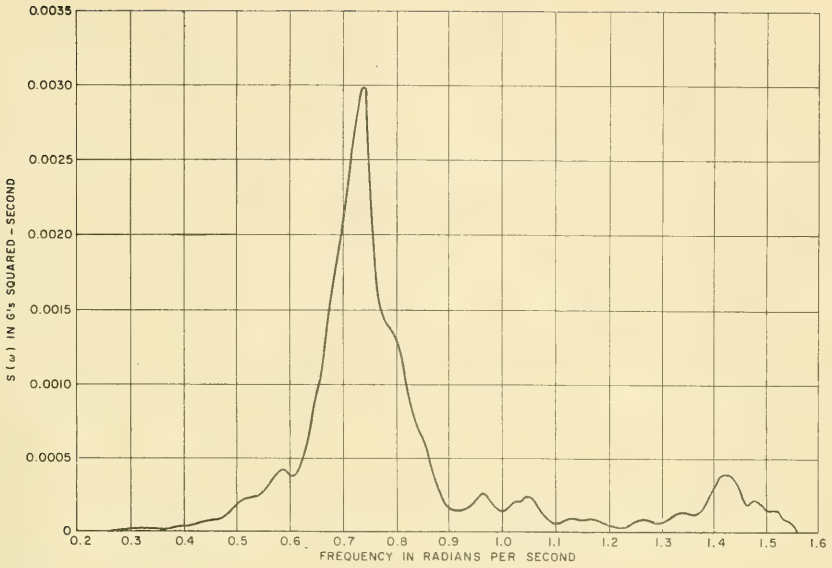


Figure 7 - Power Density Spectrum of Heave Acceleration for Condition 1 in a Head State 4 Sea

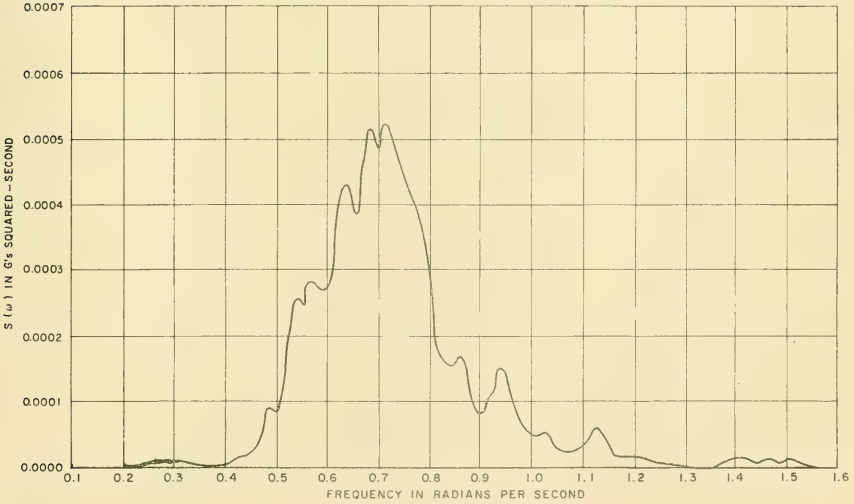


Figure 8 - Power Density Spectrum of Surge Acceleration for Condition 1 in a Head State 4 Sea

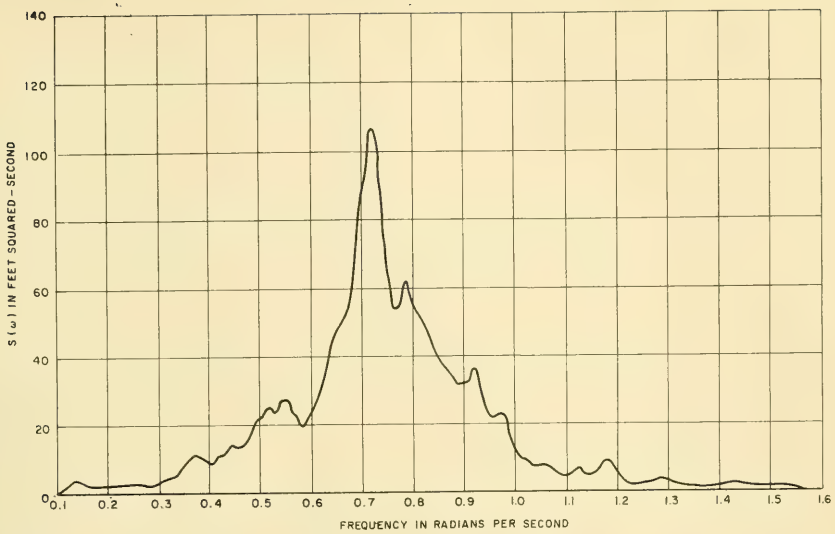


Figure 9 - Power Density Spectrum of Wave Height Used to Simulate State 6 Sea for Condition 1 Head Sea Tests

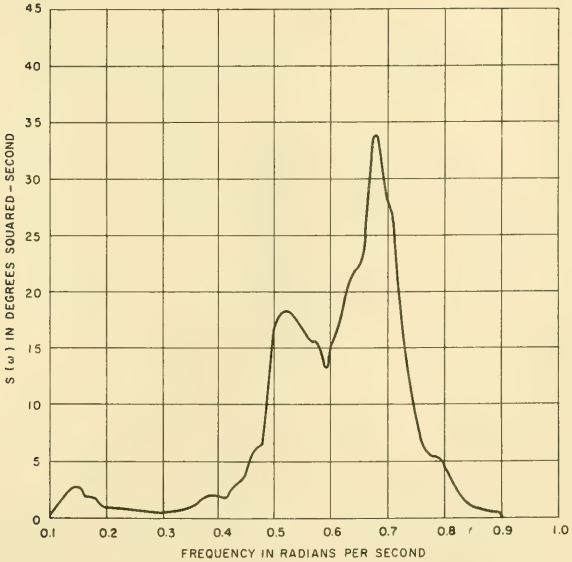


Figure 10 - Power Density Spectrum of Pitch Angle for Condition 1 in a Head State 6 Sea

Figure 11 - Power Density Spectrum of Heave Acceleration for Condition 1 in a Head State 6 Sea.

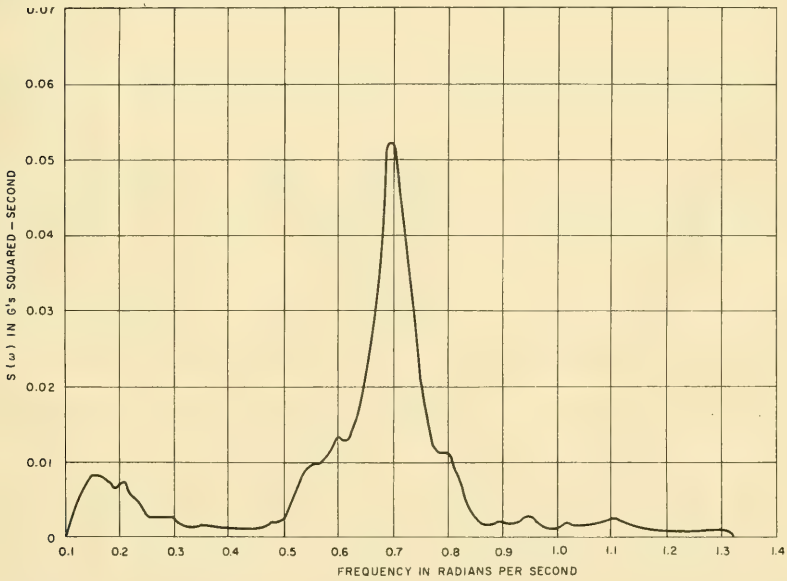


Figure 12 - Power Density Spectrum of Surge Acceleration for Condition 1 in a Head State 6 Sea

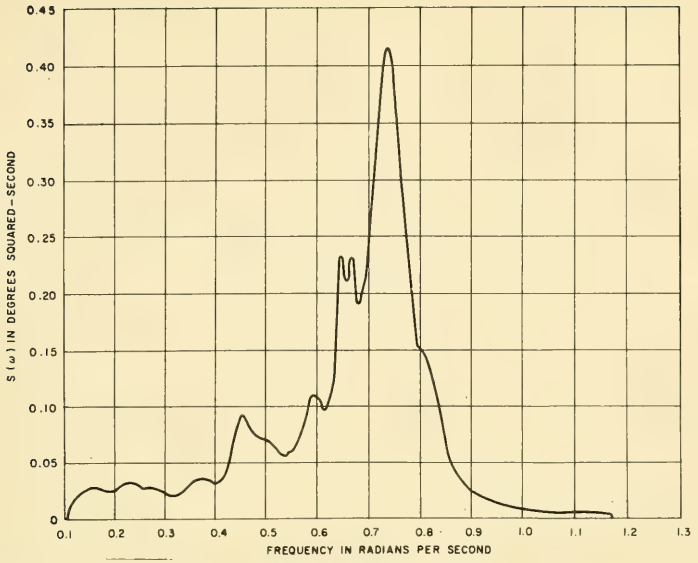


Figure 13 - Power Density Spectrum of Roll Angle for Condition 1 in a Head State 6 Sea

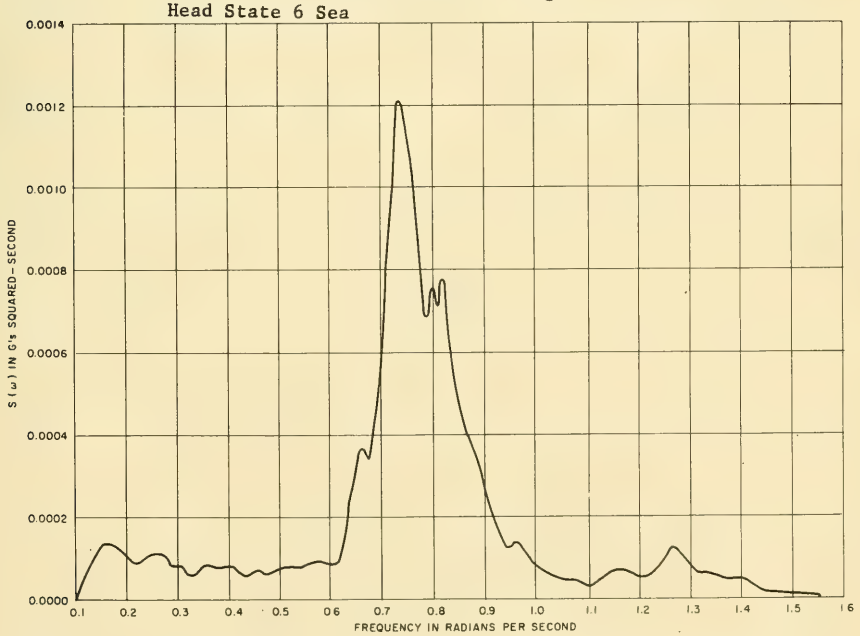


Figure 14 - Power Density Spectrum of Sway Acceleration for Condition 1 in a Head State 6 Sea

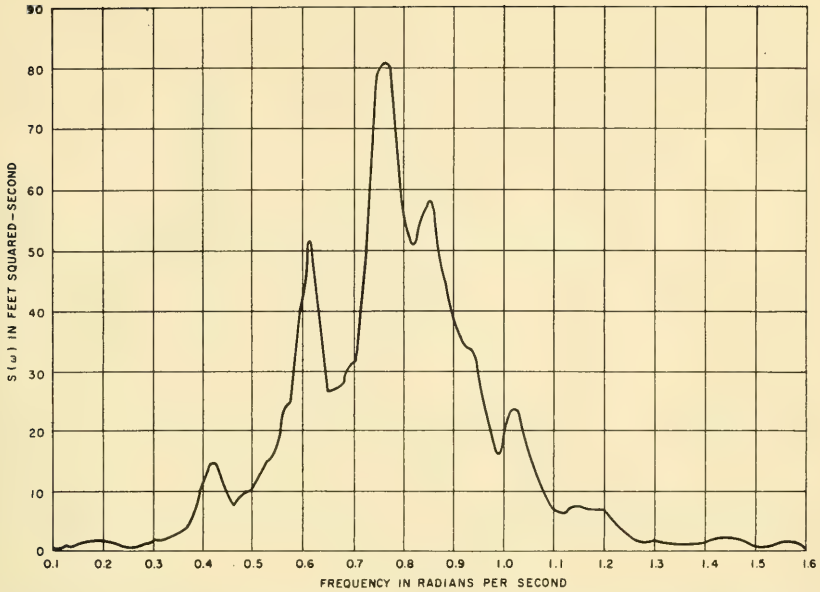


Figure 15 - Power Density Spectrum of Wave Height Used to Simulate State 6 Sea for Condition 1 Beam Sea Tests

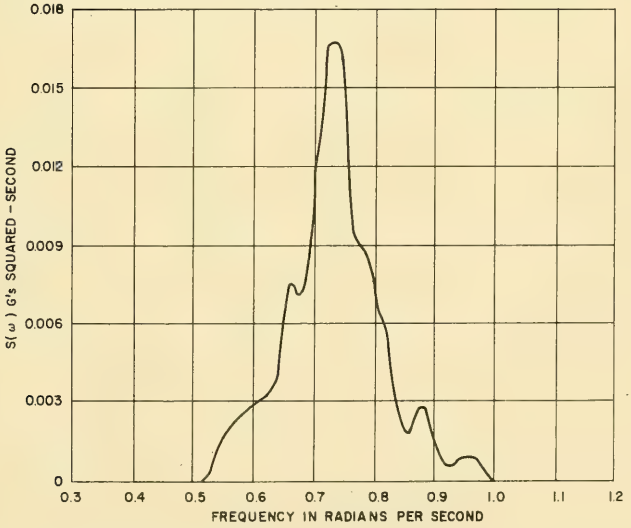


Figure 16 - Power Density Spectrum of Heave Acceleration for Condition 1 in a Beam State 6 Sea

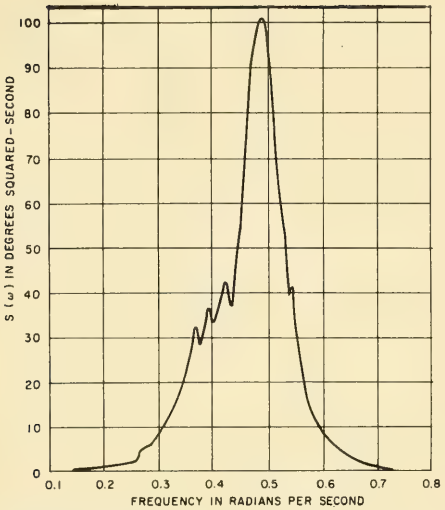


Figure 17 - Power Density Spectrum of Roll Angle for Condition 1 in a Beam State 6 Sea

Figure 18 - Power Density Spectrum of Sway Acceleration for Condition 1 in a Beam State 6 Sea

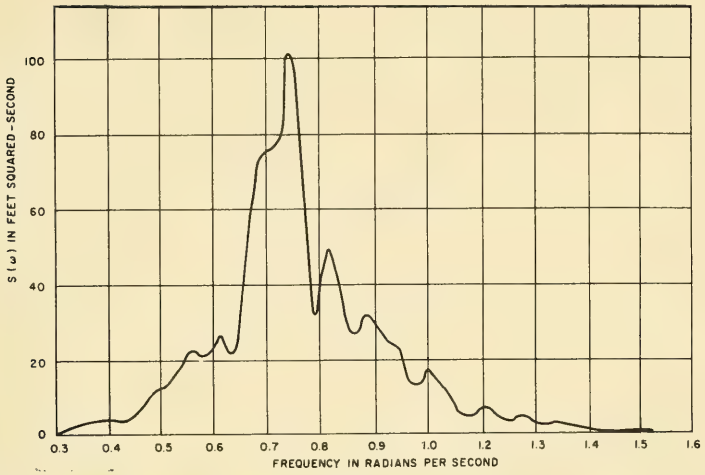


Figure 19 - Power Density Spectrum of Wave Height Used to Simulate State 6 Sea for Condition 2 Head Sea Tests

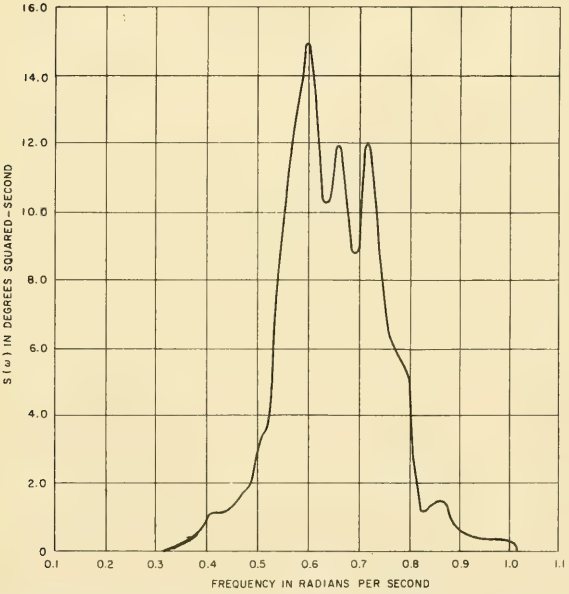


Figure 20 - Power Density Spectrum of Pitch Angle for Condition 2 in a Head State 6 Sea

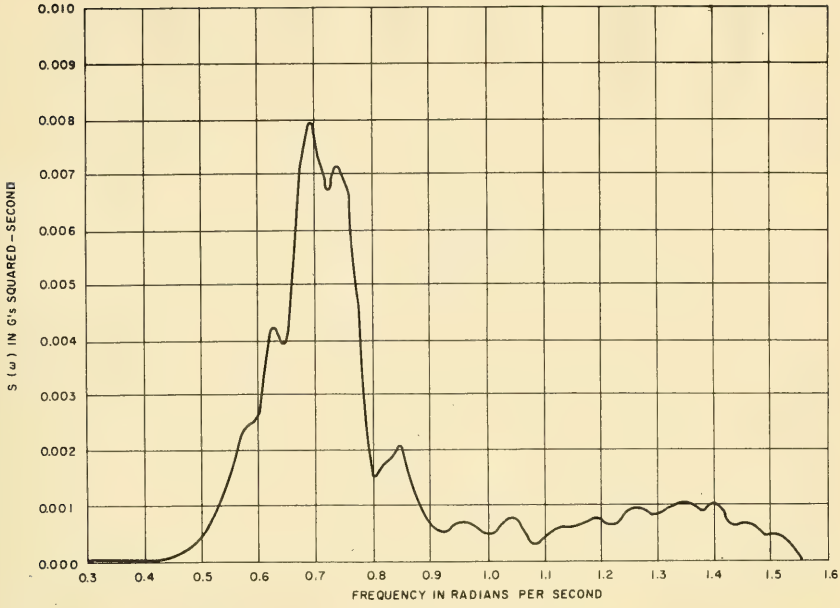


Figure 21 - Power Density Spectrum of Heave Acceleration for Condition 2 in a Head State 6 Sea

Figure 22 - Power Density Spectrum of Wave Height Used to Simulate State 6 Sea for Condition 2 Oblique Wave Tests

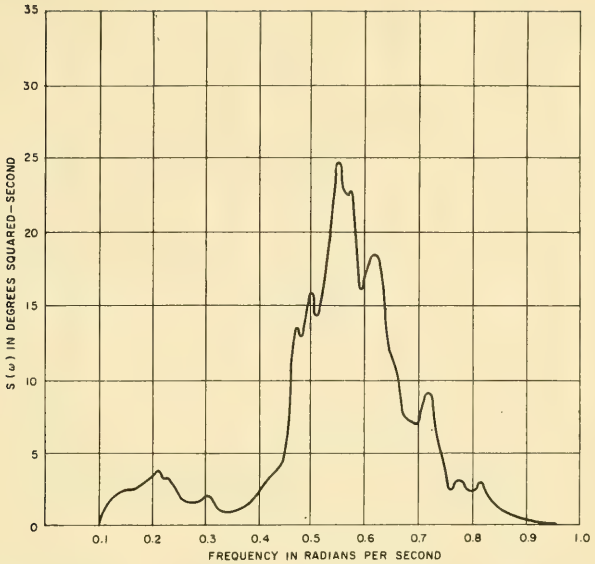


Figure 23 - Power Density Spectrum of Pitch Angle for Condition 2 in an Oblique State 6 Sea

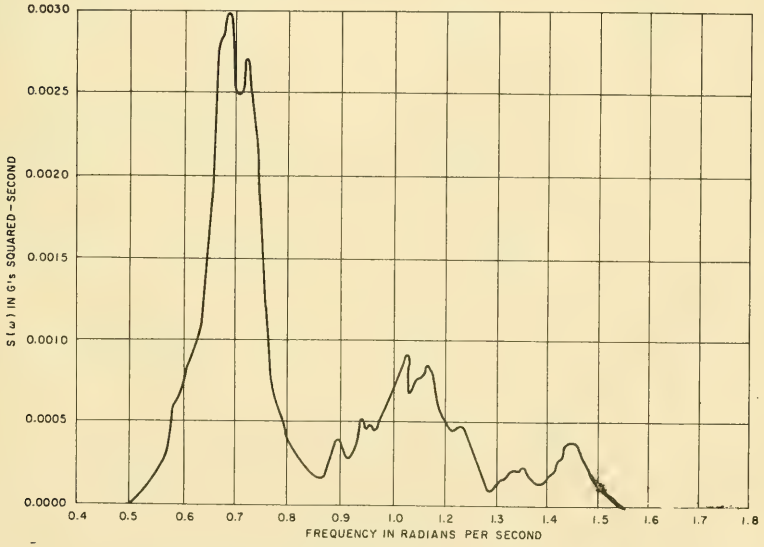


Figure 24 - Power Density Spectrum of Heave Acceleration for Condition 2 in an Oblique State 6 Sea

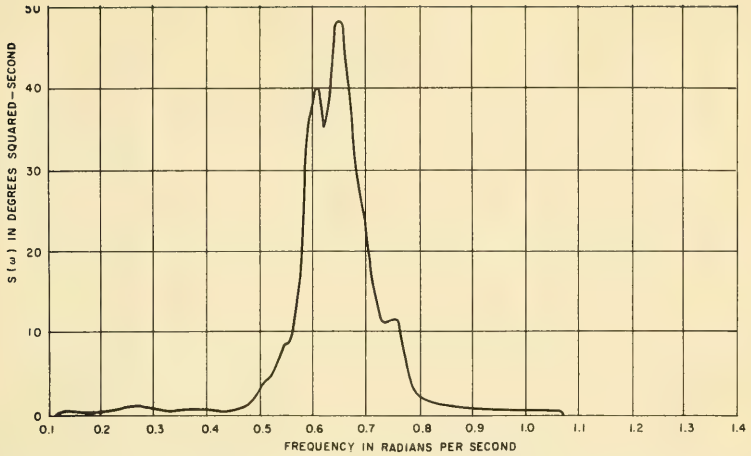


Figure 25 - Power Density Spectrum of Roll Angle for Condition 2 in an Oblique State 6 Sea

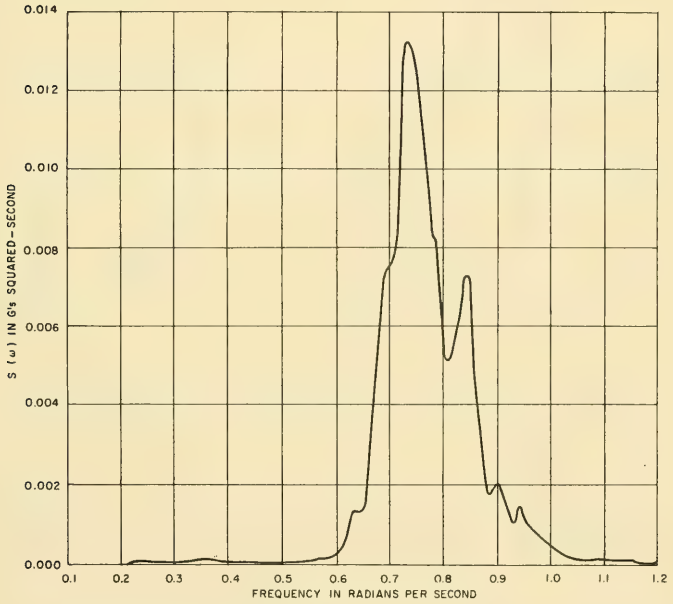


Figure 26 - Power Density Spectrum of Sway Acceleration for Condition 2 in an Oblique State 6 Sea

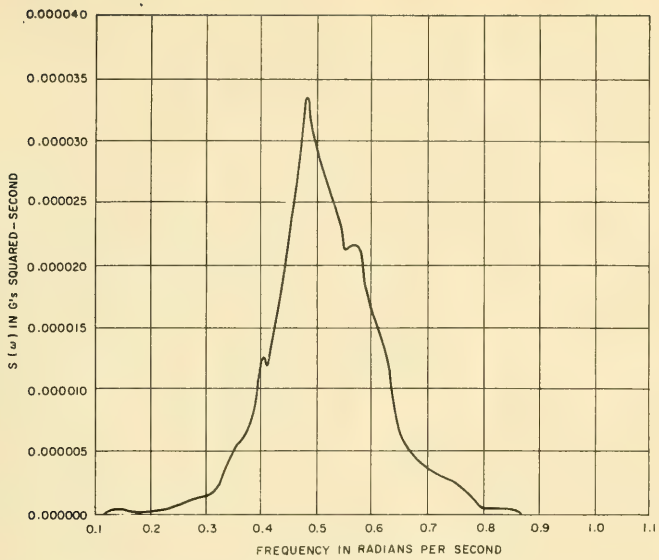


Figure 27 - Power Density Spectrum of Heave Acceleration for Condition 4 in a Head State 6 Sea

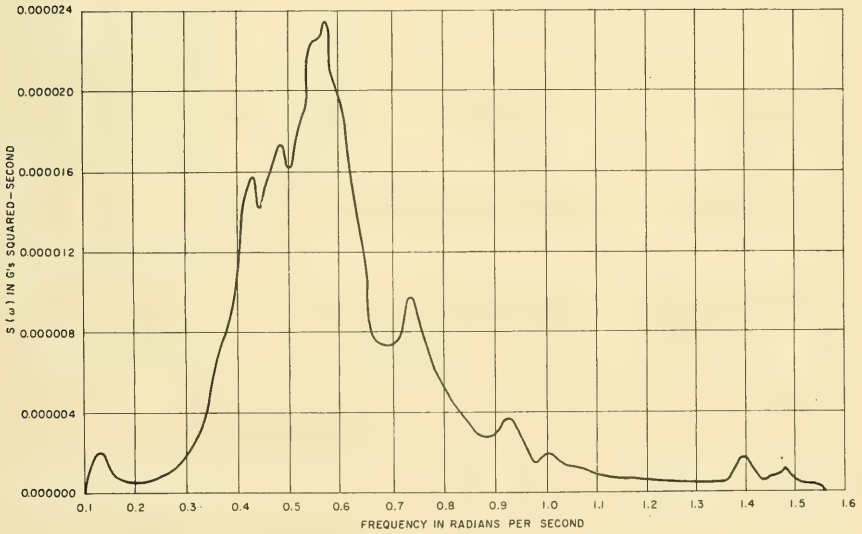


Figure 28 - Power Density Spectrum of Heave Acceleration for Condition 4 in a Beam State 6 Sea

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MOTION CHARACTERISTICS OF NRL PLATFORM (FORDS) IN WAVES, by John Foster. Aug 1964. iv, 25p. illus., graphs, tables, refs. UNCLASSIFIED

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1. Floating oceanographic research stations--Development
2. Floating oceanographic research stations--Motion--Model tests
3. Floating oceanographic research stations--Seaworthiness--Model tests
4. MASK (DTMB maneuvering and seakeeping facility)
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